Adaptive Mouse: A Deformable Computer Mouse Achieving Form-Function Synchronization

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Abstract

In this paper, we implement a computer mouse for demonstrating the idea of form-function synchronization by embedding deformation sensing modules consisting of deformable foam and Hall-effect sensors. Due to its automatic sensing, recognizing and actuating mechanisms actively responding to users' diverse gestures, we have chosen to name it Adaptive Mouse. Working with Adaptive Mouse, all users have to do is to hold it with preferred hand gestures, then through the use of their fore and middle fingers the correct button functions will intuitively be triggered. Users can also freely move the mouse and always get accurate cursor feedbacks. This "intuitive holds then clicks" action creates sense of "magic", and the mouse shape with minimum visual clues not only lowers mental loads but also achieves the goal of simplicity design.

Keywords

Computer mouse, adaptive product, intuitive interface, form-function synchronization

ACM Classification Keywords

H.5.2 User Interfaces (D.2.2, H.1.2, I.3.6): Prototyping; Input devices and strategies (e.g., mouse, touchscreen)

Introduction

The tactile sensations produced by physical shapes of computer mice often provide users more intuitive and comfort manipulation. However, the physical nature of mice shapes typically requires them to remain static in appearance and configuration [2]. This means, for example, mice carefully designed for right-handers in terms of ergonomic shapes and button locations can't be used by left-handers—at least not without problems.

Providing a neutral shape has been the conventional approach tackling this issue. Neglecting detail physical constraints of ideal mice shapes, neutral mice fulfill the minimum ergonomic requirements to serve the maximum amount of users. At the other extreme are dynamically changeable physical shapes [6, 7, 8]. With deformable materials and mechanisms, users can freely mold or inflate/deflate mice shapes to fit diverse handgrips.

However, no matter which approach is used, further manual on-screen system setups correctly mapping button functions to users' handed orientations are required. What this reveals is that even though both approaches generate proper relationships between hand sensations and mice shapes, essential constraints between mice surface shapes and the button functions related to what is found underneath it are still asynchronous.

In this paper, we implement a computer mouse for demonstrating the idea of form-function synchronization by embedding deformation sensing modules which consist of deformable foam and Hall-effect sensors. In its original form this mouse has a circular shape providing even less ergonomic and visual clues than the conventional elliptic mouse shape. However, users can deform the shape freely to fit personal ergonomic needs by holding the mouse gently. Once the deformation is generated, a user's palm terrain can be further sensed by Hall-effect sensors found underneath the mouse. After interpreting sensor data by our preliminary recognition algorithm, the orientation of handgrips are defined, the potential button locations are predicted, sensors around these locations are actuated as related input-event receivers such as click and scroll. Furthermore, signals of cursor movements generated by the optical sensor are calibrated.

These automatic sensing, recognizing and actuating mechanisms enable the mouse to actively respond to the different ways which may be held with correct button properties; hence our naming it Adaptive Mouse. Working with the Adaptive Mouse, all users have to do is to hold it comfortably, and then by using their fore and middle fingers the correct button functions will intuitively be triggered. Users can also freely move the mouse and always get accurate cursor feedback (figure 1).

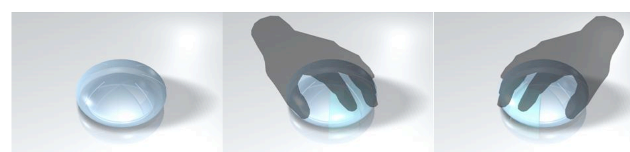

figure 1. Concept of Adaptive Mouse

Implementation

Deformation Sensing Module

A deformation sensing module consists of a piece of foam, a Hall-effect sensor and a magnet. The foam provides flexible deformation. The Hall-effect sensor detects the strength of the magnetic field and further transfers the strength into a voltage value. The closer a Hall-effect sensor is to a magnet, the higher the voltage value. We then attach the Hall-effect sensor on top of the foam and a magnet at the bottom of it (figure 2). Hence, this module is capable of detecting any deformation after which a digital signal is sent to the Micro-Controller Unit (MCU).

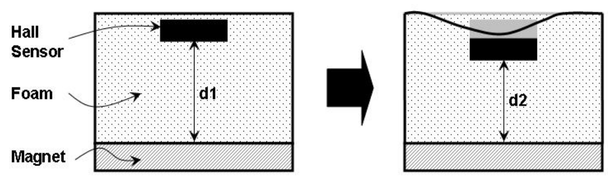

figure 2. Structure of the deformation sensing module

Physical Configuration

The physical configuration of the Adaptive Mouse is to cover deformation sensing modules on top of a chamber which is reserved for the optical sensor, batteries and essential circuit boards. Due to manufacture limitations of hand-made oriented prototyping, we only divide the circular shape into eight parts and attach 2 modules of deformation sensing on each part (figure 3). This shows that the Adaptive Mouse provides a 2 × 8 resolution of sensor signals where the palm terrain study is based upon.

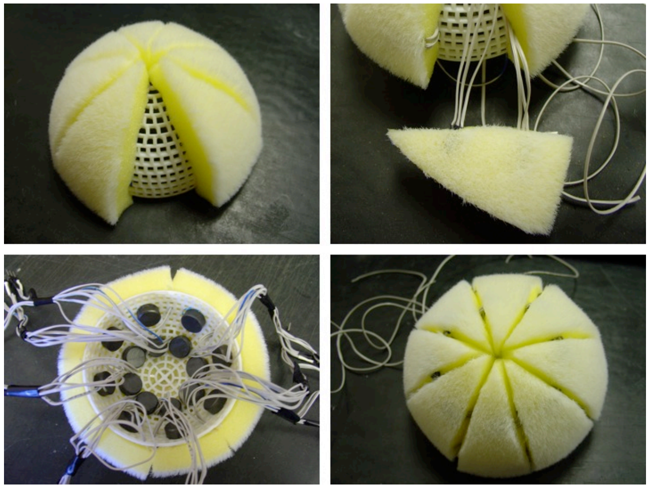

figure 3. Physical configuration and making process of Adaptive Mouse

Computational Visualization

We adopt Boarduino, a breadboard compatible Arduino Clone to collect sensor signals. Due to the limited amount of I/O pins of Boarduino, we use a popular technique, Row-Column Scanning, to enlarge the capacity of read-in signals. With this mechanism, 8 I/O pins divided into 4 inputs and 4 outputs can afford to deal with 4 × 4 signal data (figure 4). We further visualize these signals in Processing IDE to provide instant visual feedback. In detail, we create a gray scale pie chart, mapping to the circular shape of the mouse and visualizing dynamic sensor signals, to represent the palm terrain of handgrip.

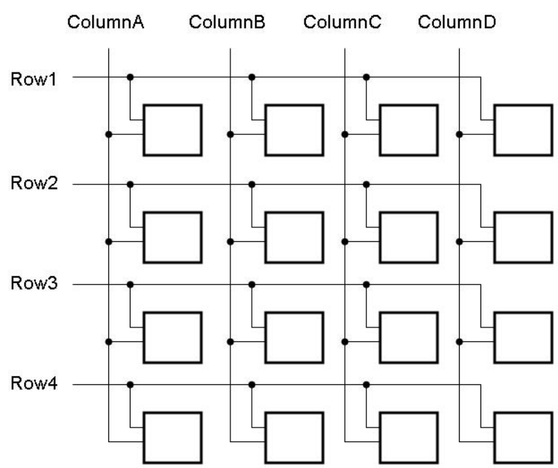

figure 4. Mechanism of Row Column Scanning.

Palm Terrain Study

In order to design an algorithm recognizing users' palms and predicting locations of users' fore and middle fingers, we have a six-step exploratory experiment with 30 subjects from 20 to 35 years old to collect palm terrain data (figure 5). There are 15 males and 15 females among these subjects and the six steps are listed as below:

- Hold the Adaptive Mouse with the right hand.
- Press with the fore-finger.
- Press with the middle-finger.
- Hold the Adaptive Mouse with the left hand.
- Press with the fore-finger.
- Press with the middle-finger.

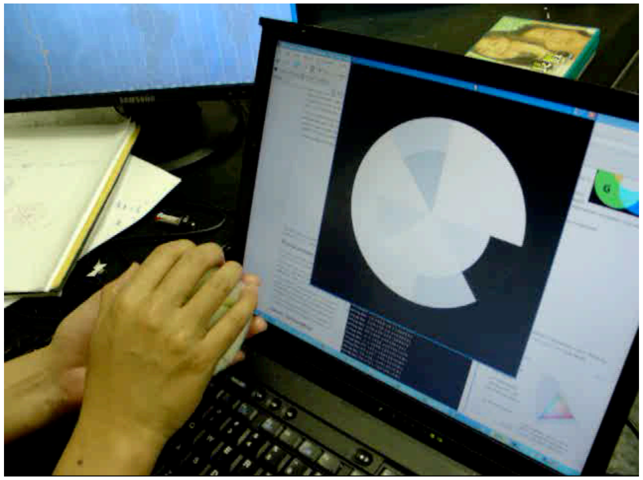

figure 5. A subject holds the Adaptive Mouse with the right hand and the palm terrain is presented on screen.

After analyzing the collected data, we find out that there are some identical characteristics among different terrains of subjects. Figure 6 shows that the dark gray area has a specific relationship with the red areas (the fore-finger) and pink areas (the middle-finger). In detail, there are 26 subjects' fore-fingers out of the 30 (87%) located at the darkest red area and 23 subjects' middle-fingers out of the 30 (77%) at the darkest pink area, while subjects hold their mouse with their right hand. There are 28 subjects' middle-fingers out of the 30 (93%) located at the darkest pink area and 24 subjects' fore-fingers out of the 30 (80%) at the darkest red area, while subjects hold their mouse with their left hand.

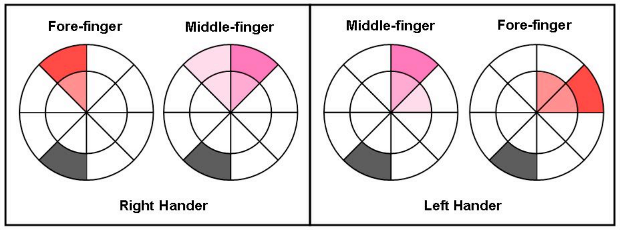

figure 6. Fore-finger and Middle-finger location analysis

Dynamic Button Location
With the experiment results above, we then design our preliminary prediction algorithm for dynamic button locations. First of all, we compare 16 signal data and look for the highest value area (tagged as the dark gray area mentioned above). Second, we predict the potential location of the middle-finger (right) button according to the highest value area, because the middle-finger button has a 77% to 93% possibility located at the opposite area of the highest value area. Third, we compare the occupation amounts of areas at both sides of the line connecting the highest area and the middle-finger button area. Finally, we predict the location of the fore-finger (left) button according to the comparison result. In detail, the location of fore-finger button will be next to the middle-finger button at the side with the lower occupation amount (figure 7). At this point the Hall-effect sensor signals beneath the fore and middle finger area will be mapped to correct left and right button events.

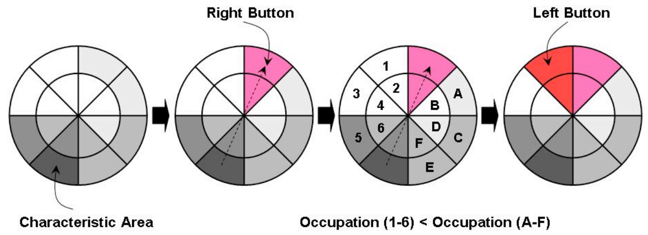

figure 7. Prediction of dynamic button location

Optical Sensor Calibration
Although the mouse shape is circular, the optical sensor beneath it is still directional. In order to make the on-screen cursor to perform correctly, we calibrate the optical sensor signal by measuring the angle between the predicted direction of a hand gesture and the original direction of the optical sensor. The calibration formula is as shown in figure 8.

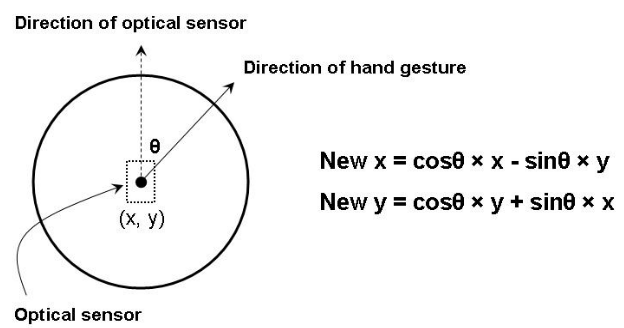

figure 8. Formula for optical sensor calibration

Exploratory User Study

After realizing the first version prototype, we invite the previous thirty subjects to use Adaptive Mouse for similar tasks listed below. All results are represented on the screen graphically and the user can easily perceive and cross check the actions they made (figure 9). User feedback on the benefit and the drawback of the Adaptive Mouse are collected after each trial.

- Hold the Adaptive Mouse with the right hand.
- Press with the fore-finger.
- Press with the middle-finger.
- Move the Adaptive Mouse.
- Hold the Adaptive Mouse with the left hand.
- Press with the fore-finger.
- Press with the middle-finger.
- Move the Adaptive Mouse.

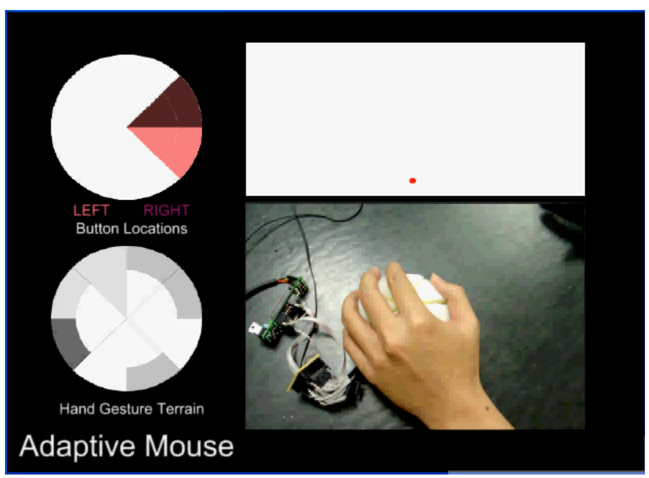

figure 9. A subject testing the Adaptive Mouse can see real time graphical feedbacks on screen.

Benefits

Most of the subjects express interest in the novelty of the mouse. This "intuitive holds then clicks" action and high-accuracy feedback makes them feel curious about the "magic" mechanisms behind it all. They even suggest that it would be quite useful to have this Adaptive Mouse in a dark presentation room where visual clues are hard to obtain. Some even mentioned that the Adaptive Mouse could solve the problem found with the iMac USB Mouse produced by Apple in 1998 which made plenty of users suffer from the disorientation of the cursor [3].

Drawbacks

Most of the subjects indicate that when they hold the mouse with only the thumb and the little finger instead of the whole palm, the button functions are wrong and the cursor is disoriented. Some female users indicate that the size of the mouse is too big for them to hold. Some also suggest that, in order to increase the tactile sensation, we should look for other material, such as moldable silicon plastic, to replace the foam.

Related works

There are many interesting mouse ideas which demonstrate the possibilities of deforming the mouse shape to fit dynamic purposes such as the Moldable Mouse [8], Jelly Click [6] and Inflatable Mouse [7].

The Moldable Mouse is a mouse that consists of lightweight moldable clay covered by nylon and polyurethane blended fabric. It enables users to shape their exact personal preferences ensuring a maximum of comfort and versatility. The buttons and scroll wheel are replaced by stick-on buttons and a touch sensitive scroll pad that can be placed at will and communicate with the mouse's innards via radio transmission.

The Jelly Click consists of a piece of soft inflatable plastic and a small flexible board where all the electronic circuits live. When not in use, the Jelly Click could be flattened as thin as possible like a piece of paper. Whenever the mouse is needed, all that needs to be done is inflate up the Jelly Click, attach the USB cable and it is a totally functional mouse once again. The Jelly Click takes mouse portability to the extreme.

The Inflatable Mouse having the same purpose as the Jelly Click is a volume-adjustable mouse. It can be inflated up to the volume of a mouse, but be deflated to store in a PC card slot of a laptop. It also provides additional pressing functions by detecting its inner air pressure of the balloon contained within it the mouse. Furthermore, it is not only an input device but also an output one by dynamically pumping in and sucking out air to generate dynamic volume effects. This demonstrates a potential idea of bi-directional input.

Also of interest, some other work irrelevant to the computer mouse design also reveals many innovative solutions about having a changeable physical shape, such as BubbleWrap [1], Volflex [5], Horev's work[4] and Harrison's study[2].

BubbleWrap is a piece of soft material providing different types of tactile sensations by dynamically actuating the electromagnets wrapped inside the soft material. It provides both active tactile feedback, using vibration, as well passive tactile feedback, using shape and firmness.

Volflex is a volumetric tactile display consisted of air balloons. The volume of each balloon can be controlled by an air pump equipped with a pressure sensor inside it. Users can shape it freely like clay and an image is further projected on its surface. Horev [4] also proposes a morphing cube that inflates according to the amount of data on a hard drive.

Harrison et al. [2] propose a technique for creating dynamic physical buttons using pneumatic actuation. Their research implements a device where buttons can be brought into and taken out of an interface under real time program control. Furthermore, because this mechanism allows the use of transparent and translucent materials, a visual display and multi-touch input sensing can be accommodated.

Conclusion and Future Work

Based on exploratory user study, we conclude some preliminary findings from our observations. First, operating a device based on mental intuition can generate a magic-like effect for users. From the design point of view, this magic feeling adds additional values on a normal consumer product fulfilling basic usability requirements.

Second, the conventional problem of operating a device with less visual clues, such as one which works in the dark or with less attention demands, can be solved by mechanisms of the Adaptive Mouse. Actually, a device providing minimum perceived affordance but still achieving maximum operational purpose can efficiently lower cognitive loads [9].

Third, the constraint of physical shape always stops designers from pursuing the spirit of simplicity. However, these constraints treated as essential elements of artifacts have the possibility of being decreased or even removed while behavior sensing, state recognition and function actuation can be embedded into artifacts.

Having said so, there are details which weren't carefully considered in this research, such as the shape size, the signal resolution, the tactile sensation and users' hand gestures. These issues definitely result in the lower accuracy, effectiveness and efficiency when performing with an Adaptive Mouse. These are going to be discussed and improved in our future study.

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